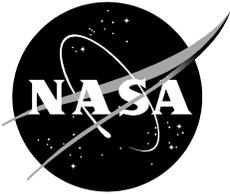


NASA/TM—2019–220302



Small Unmanned Aircraft System Off-Nominal Operations Reporting System

**Unmanned Aircraft System Traffic Management Technical Capability
Level 4 Implementation, Data Collection and Analysis**

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February 2020

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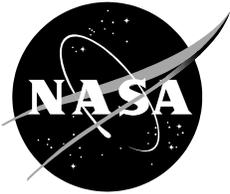
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1. Abstract

NASA performed research and development of technologies and requirements for traffic management of small Unmanned Aircraft Systems (UAS). In this effort, a small UAS off-nominal situation reporting system was developed to capture information from off-nominal situations to understand their nature and reduce occurrences. This Technical Memorandum (TM) describes the reporting system and analysis of 116 off-nominal situation reports from 352 small UAS operations, which were conducted at two flight test ranges in Summer 2019.

2. Introduction

NASA's UAS Traffic Management (UTM) Project has been tasked with research and development of technologies and requirements for a small UAS traffic management system. This system is designed to support small UAS operations in low altitude airspace, complementing the FAA's Air Traffic Management system [1,2]. The UTM Project planned a phased approach in four Technical Capability Levels (TCL) to accomplish the task. In TCL1, completed in 2015, Visual Line-of-Sight (VLOS) operations such as agriculture, firefighting, and infrastructure monitoring were addressed with a focus on geofencing and operations scheduling. Technologies and requirements for Beyond Visual Line-of-Sight (BVLOS) operations in sparsely populated areas were examined in TCL2 in 2016, and for operations over moderately populated areas in TCL3 in 2017 and 2018. TCL4 built on the earlier TCLs and focused on BVLOS operations in higher-density urban areas for tasks such as newsgathering and package delivery, and for managing large-scale contingencies [3~6].

The TCL4 demonstration in 2019 was a set of scenario-driven activities that integrated the UTM project objectives. Several scenarios were created focusing on different challenges associated with operations in a potential operational TCL4 environment, such as persistent, mixed tempo, and high-density BVLOS operations over an urban area. A total of 144 live operations were flown from June 18th to June 28th in the Reno, Nevada flight test range for some of the scenarios with nine Unmanned Aircraft (UA) made by three manufacturers. These included one vehicle from AirRobot GmbH & Co. KG, five from Drone America, and three from SZ DJI Technology Co., Ltd. Five UAS Service Suppliers (USS) developed by AirMap Inc., AiRXOS (a GE venture), ANRA Technologies, Avision Inc., and Uber Technologies Inc. supported the operations. A total of 208 operations were flown from August 12th to August 16th, and August 19th to August 23rd in the Corpus Christi, Texas range for all scenarios with nine UA made by two manufacturers, including two from 3DR and seven from SZ DJI Technology Co., Ltd. Seven USS developed by AirMap Inc., AiRXOS (a GE venture), ANRA Technologies, Avision Inc., Collins Aerospace (a unit of United Technologies Corp.), OneSky (Analytical Graphics, Inc.), and Uber Technologies Inc. supported the operations. For all operations, arrangements were made to allow only demonstration participants in the defined range. Extended VLOS operations were used to emulate BVLOS operations. That is, the UA was in sight of designated visual observers when the operator was unable to see it due to obstruction (e.g., UA behind a building) or distance, and the observers and the operator maintained a line of communication among them to keep track of the operation. Details of the TCL4 demonstration are in reference [7].

A small UAS off-nominal situation reporting system developed in the UTM project was implemented by the participating USSs for the TCL4 demonstration. This system was designed to capture information from off-nominal situations to understand their nature and reduce occurrences. To test this reporting system, scripted Communications and Navigation (C&N) off-nominal events, such as loss of Command and Control (C2) communication and degraded navigation performance, were included in the demonstration. Operators participating in such

events were directed to act as if their operation had encountered the scripted off-nominal situation and resolve the situation. The occurrence of actual (i.e., unscripted) off-nominal situations was anticipated and the operators were directed to prioritize safe resolution of the situation over scenario participation. When either scripted or actual off-nominal situations occurred, operators were required to submit an off-nominal report including a narrative of the situation to their supporting USS upon resolution of the situation. When the airborne operation became non-conforming or rogue, the report submission was required as well. A total of 116 reports were collected by USSs. This TM describes the TCL4 off-nominal situation reporting system implementation and analysis of 45 unique cases identified from the reports. Off-nominal situations data including the reporter narrative for the 45 cases are provided in the Appendix. The TM ends with suggestions for the future off-nominal reporting process.

3. Off-nominal Reporting Setup for the TCL4 Demonstration

3.1 Reporting scripted off-nominal operational situation

In each of the TCL4 demonstration scenarios, one or more scripted C&N off-nominal events were featured. Events are changes to the operations, environment, and/or conditions that elicit a response from the small UAS Operator, USS, and/or UA. In particular, there are four events designed to test C&N off-nominal operational situations, on a small or large scale. Table 1 describes these events.

Table 1. Communications and Navigation Off-nominal Event

ID	Name of the Event	Description
Test Event 10	Small-Scale Loss of C2 Link	In this event at least one but not more than 25% of UA in a scenario encounters a loss of C2 Link condition at a specific time, individualized for each encounter. Each affected UA must initiate mitigation steps.
Test Event 11	Large-Scale Loss of C2 Link	In this event at least 90% of UA in a scenario encounters a loss of C2 Link condition at a specific time and all affected UA must initiate mitigation steps.
Test Event 12	Small-Scale Loss of Navigation	In this event at least one but not more than 25% of UA in a scenario encounters a degraded navigation performance condition at a specific time, individualized for each encounter. Each affected UA must initiate mitigation steps.
Test Event 13	Large-Scale Loss of Navigation	In this event at least 90% of UA in a scenario encounters a degraded navigation performance condition at a specific time and all affected UA must initiate mitigation steps.

The operator who participated in a scripted C&N off-nominal event was required to submit an off-nominal report once the operation closed. To facilitate this submission process, USS implemented a feature to prompt the operator to file an off-nominal report when the following conditions occurred during an operation. These conditions are associated with operation states maintained by USS, shown in Fig. 1. Additional information about the states is in the USS specification [8].

1. Operation entering NONCONFORMING state
2. Operation entering ROGUE state
3. Operation entering NONCONFORMING then ROGUE state
4. Operator making UA return to the launch location, unplanned
5. Operator making UA loiter, unplanned
6. Operator landing UA, unplanned

Operation State as Maintained by USS
v20181030

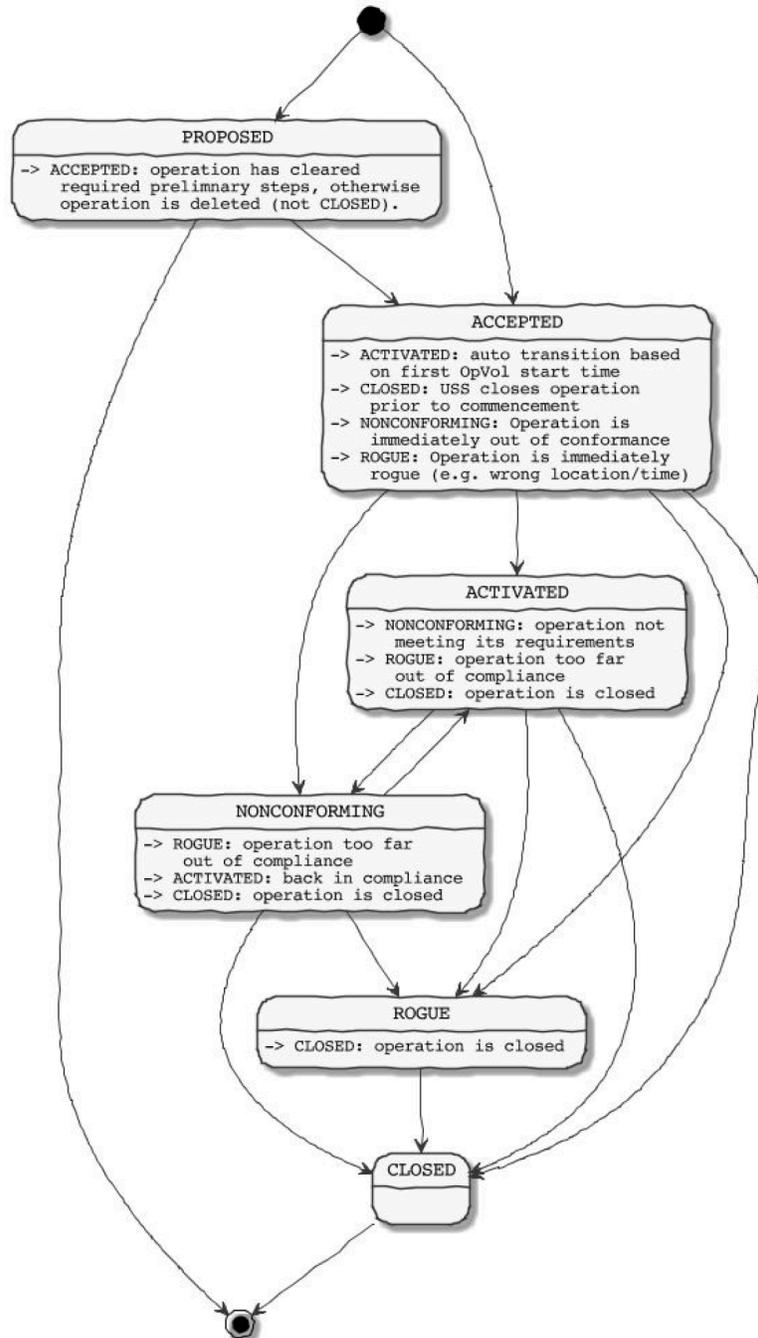


Fig. 1 Operation State Maintained by USS

USS developers were given the freedom to choose the reporting interface and prompting method as they saw fit. For example, two options were prompting operators by handing out a stand-alone device with an online survey form to the operator or opening a dialog window on the USS interface display showing a report form. A sample off-nominal reporting form provided by NASA is shown in Fig. 2.

UTM TCL4 Off-Nominal Reporting Form

(Sample, not an actual form. Note: Contact information will not be sent to NASA)

-
- Contact Information: Jung, Jaewoo, jaewoo.jung@nasa.gov, (000) 000 - 0000
 - Reason for report: ROGUE
 - Scripted off-nominal event: No
 - Date and Time of Occurrence: 2018-08-31T14:11:56.000Z
 - Describe your role and responsibility: GCS operator
 - Activated contingency plan id, if any:: 5 (RTL when UA gets no “telemetry received” acknowledgement from GCS > 30 seconds)
 - Describe communications system including frequencies used for telemetry (aircraft to operator) and Command & Control (operator to aircraft): telemetry link is via Acme cellular network, operating at 800Mhz. C2 link is via Iridium, from 1616 MHz to 1626.5 MHz. There is 900MHz point-to-point system for VLOS operations as well.
 - Reporter Narrative: Keeping in mind the topics shown below, discuss those that you feel are relevant and anything else you think is important. Include what you believe really caused the problem, and what can be done to prevent a recurrence, or correct the situation. CHAIN OF EVENTS – How the problem arose • How it was discovered • Contributing factors • Corrective actions. HUMAN PERFORMANCE CONSIDERATIONS – Perceptions, judgments, decisions • Actions or inactions • Factors affecting the quality of human performance

We filed an operation plan for news gathering mission at about 2 miles from the launch location. The plan was accepted and UA launched without any issues. However, about halfway to the destination, telemetry stopped updating for more than 10 seconds. Our system is setup to have GCS send acknowledgement signal to UA when telemetry is received and UA is programmed to loiter at a set altitude, 800 ft MSL when it does not get that ack. signal for more than 10 second. The telemetry link did not re-established and our operation became ROGUE as we hit the 30 second Telemetry Timeout. The UA is also program to fly back to launch location for safe landing when the ack. signal is not received for more than 30 second, and it did come back and we landed the UA using remote controller (900MHz).

Fig. 2 Sample Off-nominal Reporting Form (filled)

3.2 Reporting unscripted off-nominal operational situation

In the TCL4 demonstration, the director of flight operations at the flight test range communicated with the operator, visual observers, and range safety personnel to manage unscripted (i.e., actual) off-nominal situations. Public safety officers provided support when needed. When the operation encountered an off-nominal situation, the operator informed the director about the situation (e.g., “Communications with UA is lost”). The director assessed the risk posed to the public by checking with the visual observers and the range safety personnel. When a risk was identified, all airborne operations were directed to land or loiter and planned operations were halted, depending on the nature of the risk. If no risk was identified or the risk was sufficiently mitigated, the operator was directed to return to the demonstration in progress upon the safe resolution of the situation. The operator was required to submit an off-nominal report before starting a new operation.

3.3 Off-nominal Data Model

NASA provided a data model to USS implementers for submission of off-nominal reports to NASA, after the removal of Personally Identifiable Information (PII). The data model in YAML¹ format is provided as follows. The fully expanded off-nominal data model and associated models are publicly available on GitHub [9].

```
OffNominalReport{
  description:      ---- IMPORTANT NOTE ---- Please be advised: 'time_occurrence' is to
                    be included with ALL submissions of this data model (despite not being
                    listed as a "required" field). -----
  metaDataDmpUss*  metaDataDmpUss{...}
  contact          PersonOrOrganization{...}
  report_id*      string($uuid)
                  maxLength: 36
                  minLength: 36
                  pattern: ^[0-9a-fA-F]{8}\-[0-9a-fA-F]{4}\-4[0-9a-fA-F]{3}\-[8-b][0-9a-fA-
                    F]{3}\-[0-9a-fA-F]{12}$
                  example: 00000000-0000-4444-8888-FEEDDEADBEEF
                    A UUID assigned by the reporting USS for this instance of
                    OffNominalReport.
  reason_for_report* string
                    example: ROGUE
                    The reason for this report. When an activated operation enters
                    nonconforming or rogue state, includes scripted off-nominal event, or
                    unplanned RTL, loitering, landing occurs during operation, USS must
                    prompt operator to file at least one report when the operation closes.
                    Reason must be one of the following Enum values:
                    [NONCONFORMING, ROGUE, NONCONFORMING2ROGUE,
                    UNPLANNED_RTL, UNPLANNED_LOITER, UNPLANNED_LANDING,
                    VOLUNTEER]. NONCONFORMING means the operation closed after
                    entering nonconforming state. When multiple nonconformances occur
                    use the first one as the reason. ROGUE means the operation closed
                    after entering rogue state. NONCONFORMING2ROGUE means the
                    operation entered nonconforming state then rogue state then closed.
                    UNPLANNED_RTL means UA made unplanned return to the launch
                    location (e.g., due to unexpected low battery status).
                    UNPLANNED_LOITER means UA performed unplanned loitering or
                    hovering (e.g., to regain C2 link). UNPLANNED_LANDING means UA
                    made unplanned landing (e.g., due to unexpected low battery status).
                    VOLUNTEER means this report is filed in addition to USS prompted
                    mandatory one, OR filed without USS prompt (e.g., reporter requests
                    the form to be made available).
```

¹ “YAML” originally meant Yet Another Markup Language but has been redefined in recent years as a recursive acronym meaning YAML Ain’t Markup Language.

	Enum: Array [7]
scripted*	boolean <i>example: false</i> true means operation includes scripted off-nominal event. If true, USS must prompt operator to file at least one report when the operation closes.
contingency_id	ContingencyPlan{...}
role_responsibility*	string <i>minLength: 1</i> <i>maxLength: 5000</i> <i>x-utm-offnominal-prompt: Describe your role and responsibility.</i> Reporter role and responsibility. Reporter MUST see the prompt text before inputting data.
autopilot_maker*	string <i>minLength: 1</i> <i>maxLength: 1000</i> maker of UA's autopilot
autopilot_model*	string <i>minLength: 1</i> <i>maxLength: 1000</i> UA's autopilot model
gcs_program*	string <i>minLength: 1</i> <i>maxLength: 1000</i> name of UAS ground control system or program
comm_system*	string <i>minLength: 1</i> <i>maxLength: 5000</i> <i>x-utm-offnominal-prompt: Describe communications system including frequencies used for telemetry (aircraft to operator) and Command & Control (operator to aircraft).</i> description of UAS communications system. Reporter MUST see the prompt text before inputting data.
reporter_narrative*	string <i>minLength: 1</i> <i>maxLength: 15000</i> <i>x-utm-offnominal-prompt: Keeping in mind the topics shown below, discuss those that you feel are relevant and anything else you think is important. Include what you believe really caused the problem, and what can be done to prevent a recurrence, or correct the situation. CHAIN OF EVENTS – How the problem arose • How it was discovered • Contributing factors • Corrective actions. HUMAN PERFORMANCE CONSIDERATIONS – Perceptions, judgments, decisions • Actions or inactions • Factors affecting the quality of human performance</i> reporter narrative about the off-nominal event. Reporter MUST see the prompt text before inputting data.
flight_rule	string

	<p>FAA rule for the operation, ONLY to be filled when value for the variable "reason_for_report" is "VOLUNTEER". Use the following Enum values: [PART_107, PART_107X, PART_101E, OTHER] Enum: Array [4]</p>
time_occurrence	<p>string(\$date-time) <i>minLength: 24</i> <i>maxLength: 24</i> <i>pattern: ^([0-9]{4})-([0-2]0[1-9])-([01]0[1-9] [12][0-9])T([0-3][01][0-9]):([0-5][0-9]):([0-5][0-9])(\.[0-9]{3})Z\$</i> <i>example: 2015-08-20T14:11:56.118Z</i> date and time of off-nominal event in UTC. This field is REQUIRED for all Off-Nominal Reports</p>
gufi*	<p>string(\$uuid) <i>maxLength: 36</i> <i>minLength: 36</i> <i>pattern: ^[0-9a-fA-F]{8}\-[0-9a-fA-F]{4}\-4[0-9a-fA-F]{3}\-[8-b][0-9a-fA-F]{3}\-[0-9a-fA-F]{12}\$</i> <i>example: 00000000-0000-4444-8888-FEEDDEADBEEF</i> GUFIs of the operation that is the subject of this report.</p>
	}

4. TCL4 Off-nominal Reports Analysis

4.1 Experiential Reports

Experiential incident reports were collected as part of the TCL4 UTM flight test initiative conducted at the Nevada and Texas test sites between June and August 2019. There were 118 initial experiential reports in the data set, of which 72 were from the Nevada test site, and 46 from the Texas test site. Of the 46 Texas reports, 2 were determined to be duplicate reports², and were therefore removed from the data set.

In summary, there were 116 unique reports in the data set – 72 describing events at the Nevada test site, and 44 from the Texas test site. All available unique reports were screened and provided initial evaluation and classification for relevance and quality of narrative information. This evaluation and classification process is known as coding in aviation safety taxonomy. Of the 116 unique reports, 71 reports contained no, or insufficient narrative data to support analysis³, and

² Duplicate reports: TCL4 Off-nominal data set Accession Numbers (ACN) 097/098, and 103/104.

³ Limited narrative or no narrative data reports: Nevada (40), Texas (31).

45, termed “Qualified Reports” were determined to contain sufficient qualitative narrative data to perform coding and analysis.

4.2 Event Types

Initially, a team of UTM researchers created a list of off-nominal event types to describe potential events in TCL4 flight testing. This list was derived from observations from previous UTM flight testing:

- Exit lateral or vertical geofence
- Lateral deviation from flight geography
- Vertical deviation from flight geography
- Loss of aircraft control
- Airborne conflict with other UAS/unmanned aircraft
- Airborne conflict with other manned aircraft
- USS informed operator that UA was “Rogue”

However, these previously derived event descriptions were not readily matched to narrative information contained in individual reports in the data set. Therefore, a more appropriate set of event descriptions for the TCL4 data set was developed. The events descriptions and count of the events from the TCL4 test are shown in Table 2. The descriptions are applicable to the TCL4 flight test and should not be taken as a comprehensive set for UA operations in general.

Table 2. Event Counts and Description

Events	Event Description
19	C2 simulated loss (all were from the Nevada test site)
7	Non-conformance with Flight Plan and/or USS requirements
6	Ground flight control equipment problem
5	C2 loss or interruption
3	Track or heading deviation
2	Navigation simulated loss
1	Airborne conflict, with manned aircraft
1	Aircraft equipment problem
1	Potential conflict with other UA
45	<i>Unique Events</i>

4.3 Event Type Discussion

Table 2 shows nine categories to capture 45 unique events. Following associates each category with information derived from report review.

C2 simulated loss (19 of 45 reports)

Nevada conducted a simulation of loss of overall Command and Control (C2). Overall, the results were positive, with operators landing their vehicles in place, at an alternate landing site, or returning to the launch site as appropriate. Many were landed “outside of the operational volume,” but that would be considered acceptable in emergency or urgent circumstances.

Non-conformance with Flight Plan and/or USS requirements (7 of 45 reports)

In 7 incidents, operators did not or were unable to complete the programmed flight plan or were not in conformance with USS flight path and/or airspace (volume) requirements. One reporter noted that “USS does not have a means to schedule position holds.”, indicating that the USS could not dynamically update the flight plan to keep the operation in conformance.

Ground flight control equipment issues (6 of 45 reports)

iPad control issues, such as disconnection, or program failure were commonly noted in these reports.

C2 Loss or interruption (5 of 45 reports)

Several reports noted loss of communication. Two reports noted communication loss when line of sight data connection was interrupted by terrain or obstacles.

Track or heading deviation (3 of 45 reports)

In each of these reports, the reported deviation was minimal and crew were able to correct the deviation. In one event, the reported track deviation was only 3 to 5 feet.

Navigation simulated loss (2 of 45 reports)

Of the two loss of navigation reports, one reporter noted “*Simulated event – loss of navigation. Landed on Cal Neva rooftop. In real nav loss, the aircraft would not be able to navigate to a safe LZ.*”

Of the remaining 3 events, 1 involved a potential conflict with a manned aircraft. The manned aircraft event, in which the UA did not respond as planned or directed, had a 900-foot vertical separation. Therefore, a Near Mid-air Collision (NMAC), defined as less than 500 feet vertical and 0.5 nautical miles lateral, did not occur.

5. Suggestions for the Future small UAS Off-nominal Reporting Process

During the TCLs 1 to 4, the UTM project explored different options to capture off-nominal reports from the UTM-participating operations, such as running a web-form server at NASA and using a commercial online survey service. From this exploration, submission via a USS was identified as the best approach for providing a reporting interface to the operator and collecting the report. Therefore, the following requirements were included in the USS specification [8], the baseline requirements for providing UAS Services within the UTM. There is an expectation that future, operational USSs will collect off-nominal reports.

When an operation enters an off-nominal condition (which would include all NONCONFORMING and ROGUE operations), additional reporting will be necessary. For more discussion and definitions for off-nominal conditions, see [UTM-OffNominal].

[UTM-USS-076] A USS MUST obtain an off-nominal situation report from the operator for each ROGUE operation.

[UTM-USS-077] A USS MUST obtain an off-nominal situation report from the operator for each operation that has an unplanned return to the launch location.

[UTM-USS-078] A USS MUST obtain an off-nominal situation report from the operator for each operation that has an unplanned landing.

[UTM-USS-079] A USS MUST obtain an off-nominal situation report from the operator for each operation that enters an unplanned loiter.

The definition of “unplanned” in the previous requirements relates to the active operation plan at the time of the landing or at the time of the loiter. It is quite possible in these cases that the operation goes ROGUE in the process of such a landing or loiter, but this is not necessarily the case. Thus, the separate requirements are needed.

The separate requirements for unplanned landing ([UTM-USS-078]) and unplanned return to launch location ([UTM-USS-077]) stem from the way in which those landings may occur. For example manual versus automated or controlled versus uncontrolled. Through further discussion with stakeholders, these requirements may be refined and potentially collapsed or further expanded.

[UTM-USS-080] A USS MUST obtain an off-nominal situation report from the operator for each operation results in the loss of the UA.

The “loss of the UA” means either

- a total loss of the vehicle due to a crash or hard landing, or
- a vehicle that is unrecoverable due to its known or unknown landing location.

[UTM-USS-081] Whenever a USS is required to obtain an off-nominal situation report from an operator, the USS MUST do so within 3 days of the operation completion.

[UTM-USS-082] A USS MUST obtain data from the operator's platform per a Data Management Plan.

Formatting of off-nominal situation reports will be codified in the future and may allow for reporting multiple events in a single form, but currently the expectation is that for each requirement that is met above for an operation, there will be a unique off-nominal situation. So an operation that goes NONCONFORMING twice would submit two reports. An operation that suddenly loiters and then later in the operation goes NONCONFORMING would need to file two off-nominal situation reports. Again, this process will be developed further in the future to streamline as much as possible without losing potentially vital airspace safety information. Data management plan details will be published in a separate document in the future.

For the TCL4 demonstration, the USS collected off-nominal reports were sent to NASA and UTM project personnel performed evaluation and analysis. Given the scheduled closing of the NASA UTM project in FY 2020, it is suggested that in the future USSs should collect and submit off-nominal situation reports to the Aviation Safety Reporting System (ASRS) [10] so that evaluation and analysis continues to understand off-nominal situations and reduce their occurrences. This reporting should be understood as an additional process to the FAA reporting requirements. For example, operations under the Federal Aviation Regulations Part 107 are required to submit Part 107 Accident Reporting Form⁴ to report an accident.

The ASRS gathers incident reports from pilots, air traffic controllers, dispatchers, cabin crew, maintenance technicians and others via four electronic reporting forms, General, ATC, Maintenance, and Cabin, and USS can use the first three forms for submitting the small UAS off-nominal reports it collected. When USS fills the ASRS form, it is suggested to include data elements that are pertinent to small UAS operation, such as UA autopilot and ground control system information. The TCL4 off-nominal data model [9] should be used as a reference for identifying such elements.

6. Summary

As a part of NASA's UTM project, a small UAS off-nominal situation reporting system was developed and implemented to capture information from scripted and actual (i.e., unscripted) off-nominal situations, from 144 small UAS operations in Reno, Nevada and 208 operations in Corpus Christi, Texas. A total of 116 off-nominal situation reports were collected using this reporting system. From these reports, 45 unique cases were identified, and this TM provides the description of the reporting system and analysis of the 45 cases. Given the scheduled closing of the NASA UTM project in FY 2020, it is suggested that in the future small UAS off-nominal situations reports to be sent to the Aviation Safety Reporting System so that evaluation and analysis continue to understand off-nominal situations and reduce their occurrences.

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⁴ Available at <https://faadronezone.faa.gov/#/>

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UTM TCL-4 Off-Nominal Data Set

Data Set No.	1
ACN	004
Test Site	Nevada
Date	June 2019
Vehicle Make	Drone America
Vehicle Model	NavXTCL4
Reporter	RPIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	C2 loss or interruption.
Narrative	Vehicle went out of conformance mid-flight, went back in conformance before 30 seconds. Reason unknown.
Cause	Unknown
Resolution	Not Reported
Remarks	Presumed to be a scripted (planned) manned aircraft incursion.



UTM TCL-4 Off-Nominal Data Set

Data Set No.	2
ACN	005
Test Site	Nevada
Date	June 2019
Vehicle Make	Drone America
Vehicle Model	NavXTCL4
Reporter	RPIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	Non-conformance with Flight Plan and/or USS requirements.
Narrative	Takeoff window was delayed by several minutes. Vehicle went out of conformance in one volume due to missing exit window but entered subsequent volume, going back into (temporal) conformance.
Cause	Delay in takeoff forced enroute airspace timing problem.
Resolution	Not Reported
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	3
ACN	006
Test Site	Nevada
Date	June 2019
Vehicle Make	Drone America
Vehicle Model	NavXTCL4
Reporter	RPIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	Non-conformance with Flight Plan and/or USS requirements.
Narrative	vehicle was put into position hold specified by the test card for about 8 minutes. This caused the vehicle to miss its scheduled time window to move on to the next conformance volume, causing it to go rogue. Note that the USS does not have a means to schedule position holds.
Cause	Planned hold results in airspace violation.
Resolution	Not Reported
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	4
ACN	007
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	M210RTK
Reporter	RPIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	Potential conflict with other vehicles.
Narrative	Saw UVR. Invoked contingency to land safely away from UVR.
Cause	UVR.
Resolution	Aircraft was landed in accordance with contingency plan.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	5
ACN	013
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Simulated C2 loss of multiple aircraft. Was advised to seek alternate safe landing location. Landed safely but was outside authorized volume.
Cause	Simulation
Resolution	Aircraft was landed outside protected airspace due simulated airborne conflict.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	6
ACN	014
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Alerted of major C2 loss of other aircraft and told to seek alternate safe landing. Safe location landed outside authorized volume.
Cause	Loss C2 of another vehicle in the area.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	7
ACN	016
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Multiple aircraft reported C2 loss, was advised to seek immediate landing location. Landed outside of planned route.
Cause	Loss C2 of another vehicle in the area.
Resolution	Precautionary landing.
Remarks	Companion to ACN 107. Presumed to be a scripted (planned) manned aircraft incursion (repeated).



UTM TCL-4 Off-Nominal Data Set

Data Set No.	8
ACN	018
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Reports of massive C2 loss was announced via radio. Informed to find nearest safe landing location. Aircraft left volume on landing.
Cause	Loss C2 of another vehicle in the area.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	9
ACN	019
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Crew was informed C2 loss and told to find nearest safe landing location. Aircraft performed an automated land now procedure over the Pentagon Lot and landed safely.
Cause	Loss C2 of another vehicle in the area.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	10
ACN	021
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Informed of a massive C2 loss of multiple aircraft and directed to find nearest safe landing area. Landed in Pentagon lot, leaving volume to do so.
Cause	Loss C2 of another vehicle in the area.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	11
ACN	023
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Informed over radio of C2 loss and directed to find nearest safe landing area. Aircraft landed safely in Pentagon Lot and went outside volume as a result.
Cause	Loss C2 of another vehicle in the area.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	12
ACN	026
Test Site	Nevada
Date	June 2019
Vehicle Make	Drone America
Vehicle Model	NavXTCL4
Reporter	GCS Operator
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	BVLOS
Event	C2 simulated loss.
Narrative	Precautionary landing due simulated nav loss. In real nav loss, the aircraft would not be able to navigate to a safe Landing Zone.
Cause	Simulated loss of navigation capability.
Resolution	Precautionary landing due simulated navigation loss.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	13
ACN	027
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Large Scale C2 loss initiated contingency plan landing in Pentagon Lot
Cause	Loss C2 of another vehicle in the area.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	14
ACN	028
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Large Scale C2 loss initiated contingency plan landing in Pentagon Lot.
Cause	Loss C2 of another vehicle in the area.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	15
ACN	030
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Reports of large scale nav loss was reported via radio, instructed to land aircraft at nearest safe landing zone. Landed in Pentagon area.
Cause	Loss C2 of another vehicle in the area.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	16
ACN	032
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	Ground flight control equipment problem.
Narrative	IPAD became unplugged from Ground Control Station and was showing as non conforming until plugged back in.
Cause	Aircraft control equipment problem.
Resolution	Insufficient information to determine cause or result
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	17
ACN	034
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	C2 Loss, informed to land in nearest safe position. Landed in Pentagon Lot.
Cause	Loss C2 of another vehicle in the area.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	18
ACN	040
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Simulated C2 loss forced early landing at alternate landing location. Aircraft went rogue during the landing.
Cause	Simulated.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	19
ACN	042
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	BVLOS
Event	C2 simulated loss.
Narrative	Aircraft had a simulated C2 loss and returned to takeoff location
Cause	Simulated.
Resolution	Precautionary landing. Return to launch site.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	20
ACN	045
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	Non-conformance with Flight Plan and/or USS requirements.
Narrative	UVR went in place mid-route, went rogue while transiting through UVR.
Cause	UVR causes raigue operation.
Resolution	Not Reported
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	21
ACN	046
Test Site	Nevada
Date	June 2019
Vehicle Make	Drone America
Vehicle Model	NavXTCL4
Reporter	USS manager
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	BVLOS
Event	Non-conformance with Flight Plan and/or USS requirements.
Narrative	Simulated loss of NAV & went ROGUE due to going past operation time limits.
Cause	Simulated.
Resolution	Not Reported
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	22
ACN	049
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Simulated C2 loss, held in place to reestablish C2 and landed in place at designated Contingency Area
Cause	Simulated.
Resolution	Precautionary landing. Land in place.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	23
ACN	052
Test Site	Nevada
Date	June 2019
Vehicle Make	AirRobot
Vehicle Model	AR-200
Reporter	Flight Test Director.
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	Non-conformance with Flight Plan and/or USS requirements.
Narrative	Vehicle launched over GCS 1 and climbed to 150' AGL. During the climb the operator noticed that we were inside a UVR. We took imminent action to send the vehicle to a safe landing location. Landing was complete outside volume due to UVR avoidance.
Cause	Unknown.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	24
ACN	053
Test Site	Nevada
Date	June 2019
Vehicle Make	Drone America
Vehicle Model	NavXTCL4
Reporter	Data Collector
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	Ground flight control equipment problem.
Narrative	Actual RTL triggered – suspected cause UgCS software error on GCS, or possible LTE latency. No loss of navigation. No loss of C2.
Cause	Ground control equipment software problem.
Resolution	Precautionary landing. Return to launch site.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	25
ACN	054
Test Site	Nevada
Date	June 2019
Vehicle Make	DJI
Vehicle Model	M210RTK
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	C2 Loss or interruption.
Narrative	Aircraft lost connection and initiated a straight line return to home. Aircraft exited its conformance volume, but landed safely.
Cause	Vehicle/GCS communication loss.
Resolution	Ground control equipment software problem.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	26
ACN	061
Test Site	Nevada
Date	July 2019
Vehicle Make	Drone America
Vehicle Model	NavXTCL4
Reporter	GCS Operator
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	BVLOS
Event	Navigation simulated loss.
Narrative	Simulated event – loss of navigation. Landed on Cal Neva rooftop. In real nav loss, the aircraft would not be able to navigate to a safe LZ.
Cause	Simulated.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	27
ACN	062
Test Site	Nevada
Date	July 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Large Scale C2 loss initiated contingency plan landing in Pentagon Lot.
Cause	Simulated.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	28
ACN	063
Test Site	Nevada
Date	July 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Large scale loss of C2, initiated contingency plan through USS and landed safely in Pentagon Lot.
Cause	Simulated.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	29
ACN	065
Test Site	Nevada
Date	July 2019
Vehicle Make	Drone America
Vehicle Model	NavXTCL4
Reporter	PIC
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	BVLOS
Event	Navigation simulated loss.
Narrative	Simulated nav loss – route cut short & landed on Cal Neva rooftop.
Cause	Simulated.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	30
ACN	066
Test Site	Nevada
Date	July 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	Reports of large scale nav loss was reported via radio, instructed to land aircraft at nearest safe landing zone. Landed in Pentagon area.
Cause	Simulated.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	31
ACN	068
Test Site	Nevada
Date	July 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	Ground flight control equipment problem.
Narrative	iPAD became unplugged from Ground Control Station and was showing as non-conforming until plugged back in.
Cause	Ground control equipment problem.
Resolution	Reconnected iPad.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	32
ACN	070
Test Site	Nevada
Date	July 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	PIC
Scripted Event?	No
Simulated?	Yes
Line Of Sight?	VLOS
Event	C2 simulated loss.
Narrative	C2 Loss, informed to land in nearest safe position. Landed in Pentagon Lot.
Cause	Simulated.
Resolution	Precautionary landing.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	33
ACN	073
Test Site	Texas
Date	August 2019
Vehicle Make	Tarot
Vehicle Model	X6
Reporter	GSCO
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	Track Deviation.
Narrative	While on path [course], GPS began reporting right 3-5 feet from actual position, causing it to go rogue.
Cause	GPS tracking problem.
Resolution	Not Reported
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	34
ACN	074
Test Site	Texas
Date	August 2019
Vehicle Make	Tarot
Vehicle Model	X6
Reporter	GSCO
Scripted Event?	No
Simulated?	No
Line Of Sight?	Unknown
Event	Track Deviation.
Narrative	Took a turn a little wide, going rogue. [Track error.]
Cause	Not reported.
Resolution	Not Reported
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	35
ACN	080
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 210
Reporter	GSCO
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	Ground flight control equipment problem.
Narrative	The iPad/GCS application closed and wasn't sending telemetry for a few seconds till it got reopened.
Cause	GCS software problem.
Resolution	None required.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	36
ACN	085
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 600 Pro
Reporter	Operator
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	Non-conformance with Flight Plan and/or USS requirements.
Narrative	Need[ed] to loiter outside the volume so went non-conforming.
Cause	Unknown.
Resolution	Not Reported
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	37
ACN	087
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 200
Reporter	GSCO
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	C2 loss or interruption.
Narrative	UAV flew BVLOS behind building creating a low telemetry warning.
Cause	LOS communication interruption.
Resolution	UAV communication was required.
Remarks	USS does not have a means to schedule position holds.



UTM TCL-4 Off-Nominal Data Set

Data Set No.	38
ACN	088
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 200
Reporter	GSCO
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	C2 loss or interruption.
Narrative	After UAV flew behind building, low telemetry level warning came up for about a second, then came back up.
Cause	LOS communication interruption.
Resolution	UAV communication was reaquired.
Remarks	Unable to determine if pilot had sufficient notice of UVR.



UTM TCL-4 Off-Nominal Data Set

Data Set No.	39
ACN	092
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 210
Reporter	PIC
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	Ground flight control equipment problem. Non-conformance with Flight Plan and/or USS requirements.
Narrative	Emergency operation, received an alert, put drone in a loiter state. Initiated contingency plan. Attempted to use RTB button on the controller. Controller was lagging and was hot to the touch which caused an issue. New volume expired. Drone continued on original mission, going rogue.
Cause	Unknown.
Resolution	Anomaly accepted.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	40
ACN	101
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 200
Reporter	GSO
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	Ground flight control equipment problem.
Narrative	Tablet on the PIC transmitter overheated and shut down. PIC manually RTL.
Cause	Ground control equipment problem.
Resolution	Crew assumed manual control and conducted RTL.
Remarks	Flight crew may not have checked to see if UVR active before departure.



UTM TCL-4 Off-Nominal Data Set

Data Set No.	41
ACN	106
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 210
Reporter	GSCO
Scripted Event?	No
Simulated?	No
Line Of Sight?	VLOS
Event	Track deviation.
Narrative	GCSO updated the flight plan on Avison website but did not push the update to the flight controller's iPad. As a result, UAS flew according to the old/out-dated flight plan which made it go to a waypoint that no longer existed causing it to go rogue. UAS returned to the outlined path and landed with no issues.
Cause	Operator error. Executed Incorrect flight plan.
Resolution	UAS flew back into conformance from next waypoint.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	42
ACN	107
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 200
Reporter	GSCO
Scripted Event?	Yes.
Simulated?	No
Line Of Sight?	BVLOS
Event	Airborne conflict.
Narrative	On manned AC incursion, was told to loiter but was unable to on UgCS. We did get low telemetry level warnings. We reloaded FP and tried to loiter again. Unsuccessful. Manned AC was about 1000 ft. and we were at 100 ft. We continued mission.
Cause	Unable to communicate with UAS, leading to airspace violation, LTSS with manned aircraft.
Resolution	None. Vehicles de-conflicted without intervention.
Remarks	Big sky theory.



UTM TCL-4 Off-Nominal Data Set

Data Set No.	43
ACN	108
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 200
Reporter	GSCO
Scripted Event?	Yes
Simulated?	No
Line Of Sight?	BVLOS
Event	C2 loss or interruption.
Narrative	In this event manned AC incursion earlier, was able to hold (loiter) UAV, after manned AC cleared, we were unable to continue mission due to low telemetry levels. After several attempts to resume mission and/or upload mission again, we were not able to resume mission. We decided to RTB immediately.
Cause	Low telemetry levels led to inability to continue mission as planned.
Resolution	Precautionary landing. Return to launch site.
Remarks	



UTM TCL-4 Off-Nominal Data Set

Data Set No.	44
ACN	109
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 200
Reporter	GSCO
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	Aircraft equipment problem – low battery.
Narrative	Auto RTL due to low battery after WP 12.
Cause	Low battery level.
Resolution	Precautionary landing. Return to launch site.
Remarks	It does not seem that a 3-5 foot error should be considered a track deviation.



UTM TCL-4 Off-Nominal Data Set

Data Set No.	45
ACN	114
Test Site	Texas
Date	August 2019
Vehicle Make	DJI
Vehicle Model	Matrice 200
Reporter	GSCO
Scripted Event?	No
Simulated?	No
Line Of Sight?	BVLOS
Event	Non-conformance with Flight Plan and/or USS requirements. Altitude deviation.
Narrative	Having to change take off/landing elevation, I copied the same flight plane with way points in reverse. I didn't check the altitudes for that which was 70' at take off and 300' at 2nd way point which was right next to each other. Will fix on the next run.
Cause	Operator error.
Resolution	Not Reported
Remarks	